Art. XII.—*Notes on the Area of Intrusive Rocks at Dargo.*

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Introduction.

In a former paper on the geology of the Ensay district* I gave a short section extending westwards from the range on the eastern side of the Tambarra River to Mount Baldhead. If that section had been extended still further to the west it would have shown a tract of lower paleozoic rocks between Mount Baldhead and the range separating the waters of the Wentworth and Dargo rivers; thence an extended tract of intrusive quartz-diorites to a little west of the Mitchell River, and finally Silurian rocks to where, at Castle Hill, they are overlaid at a low angle by Upper Devonian formations. The sketch-section, Plate III., appended to these notes, gives the part between the eastern watershed of the Dargo River and Castle Hill.

A little to the south of the above-mentioned line of section, but parallel with its general course, there is a second outcrop of intrusive granitic rocks, which extend westwards to a point about south of Castle Hill. To the northward of these intrusive areas, which form an almost continuous series from the valley of the Tambo River, there is an unbroken stretch to beyond the Great Dividing Range of the Silurian formations, where the intrusive rock masses again are met with, rising in Mount Buffalo to the height of over 5600 feet above sea-level. To the southward of the line of section referred to the lower paleozoic sediments extend beyond Tabberabera, where they are overlaid by the Upper Devonian rocks, and again reappearing at Boggy Creek, are there seen to have been broken through by enormous masses of porphyritic granitic rocks, the denuded summits of which

* "The Sedimentary, Metamorphic, and Igneous Rocks of Ensay." Royal Society of Victoria. Read November 12th, 1885.

—Mount Alfred, Mount Lookout, and Mount Taylor—are capped by Upper Devonian conglomerates and grits.

These notes refer to part of the Dargo intrusive area. It is divided into two nearly equal parts by the Dargo River, which flows through it in a southerly direction for about six miles. The east and west extent of the area is about twelve miles. It is a comparatively low tract of hills, with smoother outlines than those of the Silurian formations which surround it, and which on the north side rise to a height of over 3000 feet. As in other tracts of similar igneous rocks, the soil is better, and consequently the herbage finer and more fattening than that growing on the surrounding hills. It is to the western part of the Dargo area that these notes especially relate.

Description and Examination of the Rocks.

No fossils have been discovered in the sedimentary rocks of this district, but there can be little doubt that they are of lower paleozoic age, and most likely Lower Silurian. The least altered examples which I have found are at Waterford, where the road to Dargo crosses the Mitchell River, and, as is elsewhere the case with this formation, the beds are alternations of quartzose sandstones, and argillaceous, somewhat slaty beds tilted at high angles. I selected two samples as being typical, and now describe them:—

1. *Argillite.*—This rock is very fine-grained in texture, and of a greyish colour, inclining to a green tint, especially on a cross fracture. It has been affected by slaty cleavage, which coincides nearly with the planes of deposit. It is faintly wrinkled and slightly shining, on the cleavage planes, with spots and strings of hematite, which lie between the latter. With the pocket-lens very numerous but minute scales of a silvery mica can be made out.

Thin slices of this rock under the microscope are found to be composed mainly of a colourless mineral in minute flakes, which are mostly arranged parallel with the cleavage. Since the thin slices of this fragile rock can be only prepared (according to my experience) from cleavage pieces, it follows that the plates of the above-mentioned mineral are parallel to the slice. When rotated between crossed nicols the spaces filled by this mineral, even when several plates are over each other, appear to remain permanently obscured; and even when further examined by the delicate tints of a quartz-plate, I could not detect any apparent change. In this ground-mass are numerous sections of minute crystals of a colourless mica, some of which are clearly foliated, and, being lath-shaped, are sections parallel to the main axis of the crystal. These latter sections polarise with a little colour, and are, I think, referable to an alkali mica, as are also the silvery micaceous scales, which can be made out on the cleavages by the pocket-lens. In addition to these, there are very numerous small granules and irregularly bounded plates of iron ore, which become translucent with yellowish to reddish tints. In places they coalesce into masses, and are then opaque. Some of these are probably hydrated iron ores, but most are referable to the hematite, which can be made out in the hand specimens. Finally, there are numerous scattered dots and larger flakes of an opaque black material—graphite. No grains of quartz are determinable.

In order to gain some information as to these various minerals, I treated the thin slice with concentrated hydrochloric acid, with occasional warming. The only effect observable was the slow solution of the iron ores, the other minerals not being appreciably affected. As the fragile nature of the thin slices did not admit of igniting them upon platinum foil, I had recourse to the less satisfactory proceeding of testing the powdered rock.

A portion of this treated with hot hydrochloric acid for some time was rapidly acted upon, the acid being strongly and characteristically coloured by iron. The solution, examined qualitatively, proved to contain much iron and magnesia and a little potassa. The residue was partly flocculent and partly a blackish powder. The former being got rid of by careful decantation, the latter was dried, and strongly ignited upon platinum foil, and rapidly lost its black colour, and on cooling was of a greyish white. When wetted with a little water I found it to be largely composed of minute scales of a silvery mica. The inference may therefore be drawn that this rock is composed of a magnesian silicate, having a micaceous structure, and apparently optically uniaxial; a mineral resembling muscovite, hematite, and probably also limonite, and finally graphite.

I also made a quantitative analysis of this rock, the results of which I subjoin:—

No. 1.—Argillite.

TiO_2	·49
SiO_2	51·33
Al_2O_3	25·69
Fe_2O_3	4·80
FeO	1·07
CaO	·25
MgO	2·72
K_2O	6·13
Na_2O	·77
H_2O	6·73*
	99·98
Moisture	1·53
Sp. gr.	2·686

In the absence of more knowledge of the nature of the minerals which form this rock, any attempt to calculate out the percentages would be purely hypothetical, and the constituent minerals are so minute that their isolation seems more than difficult. All that can be said from the examination which I have detailed is that the rock appears to be composed almost altogether of two minerals, one of which is probably a potassa-mica, and the other may belong to the chlorite group. The rock seems to be an example of those paleozoic sediments which, as I mentioned in a former paper, have undergone only the preliminary stage of metamorphism.

2. *Sandstone.*—The second example represents the sandstones of the locality. It is grey in colour, and very much indurated. Traces of the bedding remain where small argillaceous fragments are imbedded in the same plane.

Under the microscope I found a thin slice of this rock to be composed of angular grains of quartz in large amount, angular fragments of felspar, mostly orthoclase, of the character of that found in granitic rocks, others of microcline, finally a few fragments of triclinic felspars, either oligoclase or albite. The interstitial material is plentiful, and has been converted into mica, which is mostly in aggregates of minute scales, but with a few larger flakes, which have all the appearance of muscovite.

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* Including graphite.

This rock is far more altered than the argillite, and strongly resembles some samples of "Grauwacke." The argillaceous paste has been entirely converted into mica, and the rock, as a whole, greatly silicified. The silicification of the sandstones in a greater degree than the argillaceous beds flanking them I have frequently observed. In the metamorphism of the strata which converts their argillaceous paste into definitely crystallised minerals, and especially where mica is the result, silica is eliminated and again redeposited in a crystallised condition, either in the form of strings or veins, or else in the beds themselves as secondary quartz surrounding original crystalline grains in the beds. Under these conditions, it seems to me that the silica has been deposited in the quartzose beds rather than in those which were purely argillaceous. But it must be distinguished between such cases as these and the general silicification which has, in East Gippsland, for example at Jingallala, affected all the strata. I have figured in Plate II., fig. 4, an instance of the silicification of certain quartzose beds, which I have observed at Stringer's Creek, as illustrating my above remarks.

On proceeding from Waterford along the Dargo Road the transition to hornfels rock is complete within about a mile's distance. A similar change occurs in going southwards towards Castleburn, at about the same distance, or a little over. In following up the Mitchell River from Waterford the contact zone of rock is found at no great distance on the west side, and it is therefore evident that the argillites at Waterford are of local occurrence only, and are probably an easterly tongue of the less altered Silurian rocks from the extension of those rocks to the west.

I collected a set of rocks in this district to illustrate various degrees of alteration between the argillites and hornfels. The best series can be found on the road leading from Dargo to Grant.

(1.) This sample represents the argillites of the district, and was collected near Sippery Pinch, about three miles from the contact. It is slightly slaty in structure, and of a yellowish colour, due to infiltration of iron oxide. Under the microscope it is seen to be composed mainly of some chloritic mineral in small flakes, which are mostly twisted, and which, when seen on edge, have the appearance of stout fibres. The whole mass is stained by iron ochre. In the mass are a few flakes both of colourless alkali-mica and of biotite, as well as clastic grains of quartz.

(2.) This sample was obtained somewhat nearer to the contact than sample No. 1. It is grey in colour, and the planes of separation show small spots of slightly different tint, which are still clearer on weathered surfaces. A thin slice is found when examined under the microscope to be made up of a completely felted mass of minute flakes of colourless mica, with rather larger scattered flakes of brown mica. There are also a few scattered flakes of what appears to be graphite. The "spots" are lighter in colour than the rest of the rock, of much the same composition, but with less brown mica and graphite. There are no quartz grains.

(3.) This sample was collected still nearer to the contact, and about midway between it and sample No. 1. Its microscopic appearance resembles that of No. 2, but with a less fine texture. Under the microscope the structure is as in that sample, but the plates of mica are larger.

The next samples, at about a quarter of a mile from the contact, were schistose hornfels. The changes which I have noted are very much those which have been observed and recorded elsewhere in rocks of the same class. There is a gradual and more complete conversion of the argillaceous material of the rocks into mica, and as the hornfels is approached, an increase of silica, together with a final complete recrystallisation of the rock.

The hornfels rocks of this locality differ but little from those which I have described from other places and in former papers. The least altered rocks are those in which the outward general appearance of the sedimentary bed is still retained. In the most altered examples the bedding is almost obliterated, and is only clearly recognisable when the rocks are looked at in mass *in situ*.

A very common type of hornfels is plentiful in Orr's Gully. A close-grained, crystalline, dark blue, or purple, or almost black rock, which in the stream-beds, where the rocks have been laid bare, can be seen to be distinctly bedded. I selected several samples which seemed to me to be most characteristic. The first examined was a highly crystalline rock of a dark greyish black colour, and breaking with an irregular fracture.

In a thin slice I observed it to have a peculiar and beautiful structure, and one which I have also found in other hornfels rocks in parts of the Dargo area. The original structure has been completely obliterated. If it contained any clastic quartz grains in its unaltered state, such are not now recognisable. The ground-mass of the rock is composed of innumerable minute interlocking grains of quartz, which are so arranged that a number of them are so nearly optically the same that they become obscure almost at the same time when rotated between crossed nicols. These areas have in places a rounded or elliptical shape, suggesting that each may represent an original crystallisation afterwards broken into fragments, or perhaps more correctly, separated by irregular flaws. The slice thus appears composed of adjoining dark and light areas, which alternate on rotation. In this quartzose mass are innumerable flakes and rounded plates of two micas, rounded grains and crystals of magnetite, which are all aggregated more in some places than in others.

Subjoined is a quantitative analysis of this rock :—

No. 2.—Hornfels.

P_2O_5	·15
$Ti.O_2$	·17
$Si.O_2$	62·28
$Al._2O_3$	20·16
$Fe._2O_3$	·53
$Fe.O$	3·84
$Ca.O$	·82
$Mg.O$	2·54
K_2O	6·40
$Na._2O$	1·29
H_2O	1·86
	100·04
Moisture	·72
Sp. gr.	2·744

This sample was selected as apparently representing one of the least originally quartzose sediments. If this is the case, it shows in a marked manner the increase of silica, which I have before referred to, and one may also observe that, as is the case generally in these metamorphic rocks, the amount of combined water is lessened in the process of recrystallisation, together with a total removal of any carbonaceous material.

I found that still greater changes had been brought about in the sediments immediately adjoining the contact. A good example was laid open in a shaft which had been sunk upon a small auriferous quartz vein at the Perseverance mine in Orr's Gully. The contact plane at this place is nearly horizontal, and crosses the shaft about 20 feet from the surface. The beds nearest to the intrusive rock have assumed an extreme form, being almost crystalline granular, and distantly resembling the igneous rocks in appearance. A sample from this place is spotted in places with small oval patches of a yellowish tint, and which, when examined by the lens, have a crystalline-granular structure and a "granitic" appearance, being formed of felspar, mica, and quartz, showing the influence of the adjoining intrusive rocks.

Examined in a thin slice, it proves to be crystalline-granular, and to be composed of—(*a*) Very angular or even cavernous felspars, most of which are orthoclase, the triclinic felspars being both few in number and small in size; (*b*) numerous angular grains and clusters of grains of quartz; (*c*) ragged flakes and crystals of brown mica, which is in parts much bleached in colour, scarcely pleochroic, and having the iron eliminated as crystals of secondary magnetite. This mica is one of the first formed of the minerals, as it is included both in the felspars and in the quartz. (*d*) Very fibrous masses of yellow or colourless alkali mica or aggregations of flakes, or plumose or stellate groups of the same, with a few larger isolated plates. This mica seems to be a late-formed mineral, and may in part be a secondary product of alteration. There is also some magnetite, which may be original.

This sample shows the peculiar metamorphic action upon sediments immediately adjoining the contact, not only in the complete recrystallisation of the materials of the sediment, but also in the generation of felspars, which are not to be found in the hornfels rocks at a distance.

The changes which can be traced out in proceeding from the normal sediments at the outside of the metamorphic zone towards the intrusive rock masses are mainly the conversion of the argillaceous material of the former into mica of two kinds, in the general silicification of the altered rocks, and finally, near to the contact, the complete molecular recrystallisation of the sediments with the production of felspars in those beds which are at touch with the invasive rocks.

It may be inferred that not only has there been an elimination of free silica during the alteration of the sediments, but that there may have been also an accession of it from elsewhere, and also that in the neighbourhood of the intrusive rocks there may have been to some extent an impregnation by them of the metamorphosed beds with portions of their own materials.

In addition to the heat due to the proximity of the plutonic rocks, to the pressure due to the depth below the earth's surface at which this contact action took place, to the action of the mineralised waters included in the sediments, and of the additional water set free during their molecular alteration, account must be taken of the effect of vast mechanical stresses and movements to which the strata bear witness.

The normal strike of the Silurian strata of the district may be taken as about N. 30 degs. to 40 degs. W. At Dargo, for instance at Orr's Creek, I have found the strike of the metamorphosed strata east and west. It is not an isolated case, but occurs in other places—for instance, at Swift's Creek, on a large scale—and it seems probable that this extensive diversion of the strata has been due to the violent forcing of the igneous masses when in a plastic condition into the opening sedimentary beds during elevation of the earth's crust.

The Intrusive Rocks.

Aplites.—I have found it necessary to use the word aplite for a certain class of intrusive dykes and veins which I have found in places at or near to the contact, and which are very near in character to certain dykes and masses of igneous rock at Ensay and Omeo, to which I have applied that name. The word aplite is, however, not quite satisfactory if it is restricted to rocks coming under the definition "Muscovite Granites." Although in the cases to which I now refer the generality have muscovite mica in small amount, there are some which have traces also of biotite, or a small amount of biotite only. However, with this proviso I use the term aplite in this paper.*

Where the contacts can be examined, as at Orr's Creek, dykes and veins are found to cross them at various angles. They have all the main characteristics of aplite—namely, that they are crystalline-granular compounds of felspars and

* See Rosenbusch Physiographie der Massigen Gesteine, p. 19; also Die Steiger Schiefer, p. 277.

quartz, with a very small amount of mica, which in most cases appears to be muscovite. In places this alkali-mica is replaced by a brown mica, apparently biotite. Such an example I examined from a vein which crosses the contact near the saddle where the road crosses over to Dargo. A hand specimen is pale buff in tint, fine-grained, and shows small crystalline cleavage planes of felspar and grains of quartz, with very small and rare dark brown flakes of mica.

This general view is borne out by a microscopic examination. The felspars are for the most part orthoclase in irregularly formed crystals, with a few better crystallised plagioclase crystals. A few small flakes of brown mica scattered about among the grains of quartz complete the compound.

The cavernous and broken felspars point to alternations of temperature, affecting the partially crystallised magma, and also to the disturbed conditions under which the dykes were forced into opening but resisting sediments. Another sample which I collected near the same place and examined under the microscope showed me orthoclase felspars, intergrown with quartz, after the "graphic" manner of structure. There were also triclinic felspars, much eroded externally. Grains of quartz filled in the interspaces, and a few small flakes of brown mica completed in this instance also the compound.

In this rock the signs of violence are also clearly to be made out. The felspars have been much broken, and the fragments can be seen jammed into interspaces, thus showing that the rock had been in movement shortly before it had completely consolidated.

A third example from a dyke-like vein in Orr's Gully is a light-coloured and crystalline-granular rock, in which numerous shining cleavage planes of felspar can be seen; with quartz, and very minute and rare plates of black mica.

As seen under the microscope, it is composed of orthoclase felspars, in angular or cavernous crystals, which are rather larger relatively, as well as more broken and eroded, than the fewer triclinic felspars which accompany them. Some crystals of microcline also are to be seen. The quartz is in considerable amount. The mica, which is very sparsely scattered through the mass, is brown and fibrous, and only slightly pleochroic.

Of this sample I carried out a quantitative analysis, the results of which follow:—

No. 3.—Aplite.

$Si.O_2$	...	...	...	76·48
$Al._2O_3$	...	...	...	13·94
$Fe._2O_3$	...	...	...	tr.
Ca.O	...	...	...	1·08
Mg.O	...	...	...	·01
H O	...	...	...	4·90
$Na._2O$	...	...	...	3·70
H_2O	...	...	...	·86
				100·97
Moisture		...	...	·15
Sp. gr. ...		...	...	2·611

Disregarding a small amount of kaolin and of magnesia-mica, the above analysis calculates out satisfactorily for a rock composed of orthoclase, felspar, oligoclase, and quartz. The oligoclase is of the composition of ab. 6, an. 1, and therefore very near to the border of the group nearest to albite.* The orthoclase, oligoclase, and quartz are in almost equal molecular proportions.

Besides these dykes, which are characteristic of the contacts, there are also numerous other dykes, many of which traverse the intrusive masses, and perhaps more frequently than the adjoining schists. It is, however, possible that this may be more in appearance than in reality, owing to such dykes being more easily seen in the former than in the latter country.

I selected three samples of dykes as being typical of those which I had met with.

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* There is some little difference in the views expressed by authorities as to the limits of the albite and oligoclase groups, as will be seen from the following particulars, extracted from works at hand :—

	Albite.	*Oligoclase.*
Rosenbusch ...	Ab 1 an 0 to ab 8 an 1 ...	Ab 6 an 1 to ab 2 an 1
Tschermak ...	Ab ...	Ab to ab 3 an 1
Lapparent ...	Ab ...	Ab 3 an 1
Des Cloizeaux	1re classe	Ab 3 an 1 to ab 5 an 1
	2de classe	Ab 4 an 1 to ab 2 an 1
	3me classe	ab 2 an 1

Rosenbusch—Physiographie, &c., 2nd edition, Vol. I., p. 521.
Tschermak—Mineralogie, 2nd edition, p. 465.
Lapparent—Cours de Mineralogie, 1884, p. 350.
Des Cloizeaux, Oligoclase and Andesine, Tours, p. 9.

(1.) This sample was taken from a strong dyke which traverses the quartz diorites on the eastern side of the Dargo River, and it lies as rough masses on the hill-sides, where it crops out. It is compact, and of a greenish colour, weathering to a lighter tint. It has a slightly glassy lustre on a fresh fracture. Under the microscope the ground-mass contains a considerable amount of colourless basis, the remainder being innumerable minute acicular crystals of amphibole, some with ragged ends, and of all sizes, between ·008-inch and ·001-inch in length, and ·0005-inch and ·0001-inch in breadth.

These crystals lie at all angles across each other in the basis, and are slightly pleochroic. In this ground-mass there are clear and colourless simple crystals of orthoclase. This rock, therefore, is a variety of Syenite.

(2.) This dyke crosses the gap between Waterford and Dargo. It weathers into rough, reddish-coloured blocks. It is of a rather fine grain, and inclined to purple in tint on a fresh fracture. Rather numerous small prisms of black hornblende can be observed. In a thin slice I found this rock to have a ground-mass in places of a granophyric structure, but the porphyritic minerals of the rock do not in all cases form the centre of the granophyric masses. These are formed by radially concentric colourless prisms of quartz, which in places include crystals of the other minerals which form the rock. The remainder of the ground-mass contains much colourless basis throughout, in places amounting to rather large patches.

In this ground-mass are eroded crystals of dark reddish brown mica, which are pleochroic in shades of dark reddish brown and yellow. There are also numerous rather lengthened prisms of amphibole, which in cross sections show the characteristic cleavage of that mineral. The absorption is rather strong, and the colours of the rays are in shades dark chestnut brown, light chestnut red, and yellow.

(3.) This dyke crosses the quartz diorites at Orr's Creek, and is of a somewhat peculiar character.

It is black in colour, weathering to greyish-black. In fresh fractures one can observe numerous small shining flakes of pinchbeck to black coloured mica, with pyroxene and some larger isolated felspars. Owing to the extremely dark tint of the ground-mass of this rock, it is most difficult to prepare a thin slice in a satisfactory manner. The ground-mass is partly a very dark-brown basis and partly of exceedingly numerous microliths, being minute, stout, and often twisted fibres or grains, the result of devitrification. These are collected together much more in some places than in others. In this ground-mass are:—

(*a.*) Magnetite, in rounded crystals and grains.

(*b.*) Colourless prisms and crystalline grains of augite. These are not only porphyritic, but also descend in size to almost microscopic dimensions in the ground-mass. In places the augite is in clusters of angular grains, which seem to be the crushed remains of crystals. These clusters of grains are enveloped in the mica next to be mentioned.

(*c.*) Dark brown red mica, in which the absorption is strong, the rays being orange-red, and almost colourless.

(*d.*) Serpentinous pseudomorphs, after olivine. In some of them the form of the original mineral is still preserved, together with the meshed appearance produced by the fractures which characterise it.

(*e.*) There are also a few crystals of felspar, which are not striated, but which have not the form, and do not obscure after the manner of orthoclase.

This rock consists essentially of a ground-mass, containing some basis, and having porphyritic crystals of augite and mica in about equal amounts; the olivine about half the amount of either, and the felspar quite subordinate.

The peculiar features of this rock, and the occurrence of the colourless augite, together with the olivine pseudomorphs, lead me to think that the rock is pretertiary in age, and, according to the classification I follow in these notes, a very basic variety of Diabase (Olivine-diabase).

Quartz Diorites.—So far as I have examined them, the massive intrusive rocks of Dargo belong to the diorite group. Most commonly they are light in colour, but in places the mica or the amphibole, or both, increase so much that the rock necessarily has a darker shade of colour than in those examples, in which the felspar and the quartz are more abundant. In almost all cases the rock is a quartz diorite, but I have met with places where the quartz almost, if not quite, disappears. Such rocks are found in parts of Orr's Creek, and a sample, to which I shall refer later on, was collected near where the sketch section on Plate III. crosses it.

As in other parts of Gippsland, these diorite rocks weather much more rapidly than the surrounding sediments, and, as a consequence, the Dargo area forms an extensive basin of hills, which are low and rounded as compared with the towering Silurian mountains which surround them. But wherever within this area traces of the zone of contact rocks still remain undenuded, the hills are rough and rugged. The vegetation also invariably tells the observer the character of the rocks, for the diorites decompose into a soil of better quality, clothed with more nutritious grasses, and the forests are less dense, and are of different eucalypts than on the Silurian formation.

The sample which I selected for examination from the varieties of diorites is of the more basic kind. The other samples strongly resemble similar rocks which I have described from Noyang and Ensay.

The rock under examination is a crystalline-granular compound of medium texture, in which by the pocket-lens plagioclase felspars, dark green to almost black hornblende, traces of black mica, and very little quartz can be made out. The rock is somewhat darker in colour than the generality of the diorites of this neighbourhood. When examined under the microscope it proves to be composed of the following minerals:—

(*a.*) A little magnetite, in somewhat larger crystals than are usually found in these rocks.

(*b.*) Amphibole, in very cavernous crystals. Some are twinned in the usual manner, and I measured obscuration angles up to 20 deg. Pleochroism is not strong in shades of brown. The mineral has become fibrous, and is also much chloritised. In places small clusters of talc-plates have also resulted from alteration.

(*c.*) Triclinic felspars, which predominate in amount somewhat over the amphibole. Some of the felspars are broken and crushed, as, indeed, are some crystals of amphibole. The felspars are more or less kaolinised, but in an inequal manner. The size of the felspars crystals differs, some being large and very compound, and having somewhat the appearance of oligoclase. Others are smaller and more simple. The latter are better developed than the former. These differences suggest two generations of felspars.

In the slices which I prepared there were but few sections of these felspars in which reliable measurements of the obscuration angle could be obtained, and these were all in the plane $OP — \infty\bar{P}\infty$. The values thus obtained were from 3 degs. to 23 degs., thus suggesting a soda-lime felspar on the border between Andesine and Labrador. This, however, assumes that the measurement of 3 degs. was taken in the plane OP (001); a less angle would still be in the Andesine group, unless it were less than 1 deg.* It also assumes that only one kind of plagioclase occurs in this rock, which is not at all certain.

(*d.*) A very small amount of quartz, in homogeneous portions, filling spaces between the minerals, otherwise resembling that of the granitic rocks.

The subjoined quantitative analysis is of this rock. No mica was observable in these slices:—

No. 4.—Quartz Diorite.

$Si.O_2$	52·03
$Al._2O_3$	20·57
$Fe._2O_3$	1·60
$Fe.O$	6.97
$Ca.O$	7·80
$Mg.O$	5·39
K_2O	1·34
$Na._2O$	2·37
H_2O	1·27
	99·34
Moisture	·26
Sp. gr....	2·855

In order to be able to calculate with some degree of precision the percentages of the rock-forming minerals from this analysis, it would be necessary to have a knowledge of the composition of the amphibole and of the felspars. An estimate of the probable composition of the rock can, however, be made by calculating the felspars out on the basis of the optical measurements, and also the alteration products in the assumption that the H_2O indicates kaolin and chlorite, which, according to the microscopic examination, would probably be in the proportion of one of the former to

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*	*Formula.*	*Obscuration angl on O.P.* (001).
Oligoclase	Ab 2 an 1	3° 35′
Andesine	Ab 3 an 2	2° 12′
Andesine	Ab 4 an 3	2° 58′
Labrador	Ab 1 an 1	5° 10′

Rosenbusch—Physiographie, &c., 2nd E., p. 535.

three of the latter. The remaining molecular proportions should then give the amphibole, with a small remainder of silica representing the free quartz. In this calculation the small amount of Fe_2O_3 is regarded as indicating the magnetite, and the minute amount of talc is disregarded. The ratio between the remaining components which are thus assigned to amphibole are such as to fall within the limits given by Rammelsberg for an aluminous hornblende, being Al_2 to $\overset{\text{II}}{R}$ as 1· to 3·, and $\overset{\text{II}}{R}$ to Si as 1·5 to 1·* Taken in percentages, the rock may accordingly be composed as follows:—

Magnetite	2·34
Kaolin	5·69
Chlorite	9·72
Andesine	36·55
Hornblende	33·55
Quartz	12·15
	100·00

Auriferous Veins in the Dargo Area.

Gold-mining has been carried on for many years in various parts of the intrusive areas referred to in these notes. Alluvial gold in payable amount has been found at Dargo, Tucker Creek, Granite Creek, and other places, and in less amount is almost everywhere to be met with in the gravel of the streams. The alluvial gold is either in small laminated flakes or in ragged pieces, according as it is found in the larger streams, or in localities near to the veins from which it has been set free. In a number of places small gold-bearing quartz veins have been discovered, and at Tucker Creek, Budgee Budgee, and Orr's Creek such have been more or less worked.

At Orr's Creek, to which place these notes especially refer, a number of small quartz veins have been worked for several years back in the hornfels rocks immediately adjoining the contact with quartz diorites. This mine is called the "Exhibition," and I now give some particulars concerning it, which are of interest, as showing the character of the small quartz lodes and veins, the wearing down of which has set free the alluvial gold of the district.

* Mineralchemie, page 418.

The Exhibition mine has been opened out at about half a mile south of the road leading from Waterford to Dargo, and not far from the low saddle on the divide between the Mitchell and Dargo waters. It is on the contact of the quartz diorites with the sediments which are there metamorphosed into hornfels. The angle of dip of the hornfels beds at the mine varies within short distances on a nearly east and west strike. I found, in examining the workings of this mine, that the gold is in very narrow veins of mineralised quartz not exceeding six inches in width, and in some cases being hardly more than a quartz lining to the partings of the rock. The veins fill narrow fissures passing up through the metamorphosed sediments from the contact plane, and, so far as I could observe, not passing down below it into the plutonic rocks. The gold is in small particles, some being so minute as to resemble "gilding." It is not confined to the veins of quartz, but is occasionally found in the hornfels rock in places where that rock is very silicious. Together with the gold are ordinary iron pyrites and galena. There are a number of thesevery narrow veins within certain limits of about three feet wide, thus defining what in miners' language may be termed the "lode country." At one time it was attempted to work and crush the whole of this width for the sake of the gold contained in the narrow veins and small strings of quartz in the hornfels, but the extreme hardness of the rock and the comparatively small amount of gold caused the attempt to be given up.

In Plate I. I have given a horizontal section of the mine as I saw it in 1883 in the middle adit, and on the same plate a set of four cross sections of the lode. These will explain better than words some of the features of this mine. Since the time of my visit the mine has been worked from time to time when water was available, with results to which I will now refer. For most of the facts outside of my own knowledge I am indebted to the courtesy of Mr. J. B. Kelly, J.P., of Dargo, who, as mining registrar, and also as a shareholder in the Exhibition Company, has had opportunity of knowing the whole course of the mining operations from the first. To Mr. Stellwag, of Sale, the legal manager of the company, I have also to express my obligations for freely giving me the information in his possession.

The Exhibition mine was discovered by the brothers Jorgensen, who are known as enterprising prospectors. To work it the Exhibition Gold-mining Company (No Liability) was formed, in which the prospectors held one-half of the shares, the remainder being held by two shareholders in Sale, with the exception of a few shares held at Dargo and Bairnsdale. A steam-engine, working a battery of eight stampers, was erected at the mine, which was managed for the company by one of the shareholders (Mr. H. Jorgensen). The gold obtained, of which I subjoin a tabulated return, was from the stone only, and not from the pyrites, which has not been separated from the tailings or treated in any manner. The company is still constituted as above-mentioned, and up to the end of May, 1886, had produced an amount of gold equal in value to the total cost of machinery and labour. The mine and machinery are at this time let on tribute.

Year.	Number of Tons of Quartz Crushed.	Total Yield.
		oz. dwt. gr.
1881	145	142 0 0
1882	364	258 13 10
1883	201	196 5 5
1884 to June 9, 1886	481	417 14 0
1881 to June 9, 1886	1,191	1014 12 15

The yield of gold varied from 9 dwts. 19 grs. to 1 oz. 6 dwts. per ton of quartz.

The interest attaching to this mine is due to the evidence it affords that such narrow auriferous veins as those at Orr's Creek may, with careful management, even be capable of yielding a profit. To this subject I shall refer again later on. Mr. Kelly informs me that the gold from the Exhibition mine was worth £4 per oz., which would agree nearly with a composition of Au. 94·20, Ag. 5·80. This proportion is higher, as to the gold, than I should have expected in the Dargo area. Some years ago I examined a series of samples of alluvial gold from different geological formations in Gippsland and at Omeo, with the result that I found the composition in Silurian areas to lie between the proportions of silver alloy to gold of 1:12 and 1:40, and in areas of metamorphic or plutonic rocks of 1:2·2 and 1:9.*

* A number of these determinations were recorded in Reports of Progress, II., p. 69, and III., p. 238, Geological Survey of Victoria.

This difference in composition in gold from the two classes of areas can be seen in two assays which I now give, in addition to the former, for the purpose of illustration. A is alluvial gold from the Silurian formation at Crooked River, and B alluvial gold from the metamorphic area of Dargo.

	A		B
Au.	96·923	...	82·969
Ag.	2·564	...	16·055
Oxydisable Metals and loss	·492	...	·917
	99·979		99·941

The connection which I have here noted between the geological formation and the amount of alloy with the gold seems not to be confined to the districts I have referred to. An examination of the reports of mining surveyors shows reason for suspecting that there is a similar connection between the geological formation and the composition of the gold found in it throughout Victoria.* But it is not so clearly to be made out, because the highest and lowest price paid for gold in any locality is not always necessarily for gold raised there, but also includes gold brought from other places.

The subject is an interesting one, and capable of throwing light upon the source of the gold, and also upon the processes which have been at work in depositing it in the quartz reefs. But it would require much labour to work it out in a satisfactory manner. Examinations would have to be made both of reef and alluvial gold from the same locality, and of reef gold from different parts and depths in the same mine. This should be repeated in many places and in different formations. In connection with such a series of examinations there should be also another of the local rocks, and also of rocks taken from different depths and places in the several mines from which the gold had been collected for examination.

The comparison of such gold assays, and of the microscopical and chemical examinations of the rocks, would, in all probability, lead to some conclusions as to whether the

* Reports of the Mining Surveyors. Published by the Department of Mines. "Table showing the lowest and highest prices paid for gold." Years 1880 to 1885.

gold has had its source in the Silurian, metamorphic, or igneous rocks, or in connection with them.*

In two other places not far from Dargo other similar contact reefs have been opened and partly worked, one at Granite Creek, at the extreme western end of the series of intrusive areas, and the other at the extreme eastern end, at Tucker Creek.

A few words about them will be of use in truly estimating the evidence given by the Exhibition mine. The Budgee Budgee mine at Granite Creek in so far resembles the Exhibition mine that it is at the contact of the quartz diorites, with presumably Silurian sediments. But the contact plane has been denuded, and the quartz lode is found in the plutonic rock. The strike of the lode is east and west, dipping from 40 degs. to 50 degs. to the north. When I visited the mine while it was being worked, several years ago, I found a tunnel driven in the western side of Granite Creek, on the course of the lode. The quartz vein being worked was from 6 to 9 inches wide; but it only formed part of the lode, which I found to be nearly 3 feet between the walls. I have given a diagram of the lode as I then saw it at the face of the tunnel in fig. 2, Plate II.

An incorporated company was formed to work this mine. Machinery was erected of a kind not adapted to the nature of the stone to be operated on. A good deal of work was done, with little result, and finally the company was wound up, and the mine abandoned. At the present time the mine has been re-occupied by a party of working miners.

The standard of the gold at this place is somewhat low, and falls in near to that obtaining in other igneous or metamorphic areas in Gippsland. According to information obligingly communicated to me by Mr. Horace Rich, of Sale, a former shareholder in the Budgee Budgee Company, the gold from that mine was worth £3 17s. A sample of alluvial gold which I examined from Granite Creek, close to this mine, I found to be composed of 90·05 per cent. of gold, and 9·95 per cent. of silver.

At the sources of Tucker Creek, a small stream which flows into the Wentworth River, there are a number of quartz veins at the contact of the quartz diorites and paleo-

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* Henwood makes the remark in "Observations on Metalliferous Deposits" (Transactions of R. G. S. of Cornwall, Vol. VIII., p. 359) that in Brazil "detrital gold . . . is always of better quality than mine gold of the neighbourhood."

zoic sediments. In Plate II., fig. 1, I have given a diagram of one of these veins, where it had been laid open by a shaft close to the contact. When these quartz veins were discovered to be much mineralised, and to contain some gold, a "no liability company" was formed to work them. A shaft was sunk, and a tunnel was driven along the course of one of the larger reefs. Trial crushings were taken out at three different places, and tested at the Good Hope battery at Grant, with a yield of 11 dwts. to the ton; at the Normanby battery, yielding 8 dwts. to the ton; and the third at the Budgee Budgee mine, giving a return of 15 dwts. to the ton of stone. Finally a favourable report was made as to the prospects of the mine by an expert, and upon this a steam-engine, driving a battery of ten stampers, was erected, and a considerable amount of preliminary work was done. Hereupon a crushing was had from the mine, with the result, according to some statements, of 1 dwt. per ton, and, according to others, of nothing at all. The whole enterprise was now dropped, the company was wound up, and the battery was sold and removed elsewhere, after an expenditure of about £2500. It is not proved, however, that these reefs at Eureka are so absolutely valueless as has been assumed They are highly mineralised, and the appliances were probably—as was the case elsewhere in the district—not adapted to the treatment of such stone. Moreover, the trial crushings, if *bona fide*, show that some of the veins were auriferous, although not in a great degree, yet far more so than the one crushing made at the Eureka battery would indicate.

The ill-success which in the past has attended attempts to work such reefs as those at Dargo and its neighbourhood makes it desirable to trace out the causes of failure, and also to ascertain whether it might not be possible, in the future, to work them remuneratively. Conclusions arrived at by considering these cases will also apply to other similar auriferous reefs in Gippsland.

It is well to say that the experience of the past, taken as a whole, has been unfavourable. In no single instance with which I am acquainted have such reefs as these been worked at a profit by incorporated companies. The Exhibition mine is not an exception, for no profit has been made, and the return to the shareholders of their expenditure on machinery and labour is due, as I see it, to the fact that the mine has been managed and worked in the greatest part by the shareholders themselves, who had a direct interest in economy of working. It has not been the result of richer stone, or more of it, for the quartz veins in this mine are exceptionally narrow, and contained little, if anything, over the ordinary yield of gold in other similar mines. It has been due to careful and economical working, and the shareholders have contended, with some success, against difficulties under which other mines have succumbed.

Some of the difficulties in the way of working this mine at a profit have been, in addition to the narrowness of the quartz veins, the hardness of the country containing them, thus making the cost of raising stone for crushing out of proportion to the yield of gold. The crushing plant was not adapted to the separation and saving of the gold from the ores accompanying it. Moreover, so far as I am aware, there was not sufficient check kept upon a possible loss of gold through the injurious action of those minerals upon amalgamation; in other words, it was not known how much gold was lost through this cause or with the pyrites, which were not saved. The want of water at times also caused loss of time through stoppage of work and delay.

As against these drawbacks, the company was a small one. The mine was managed, and partly worked, by the shareholders, which favoured economy.

The inference is justified from these statements that, had the gold-bearing veins not been so exceptionally narrow, the hornfels containing them not so hard to work, the appliances for treating the stone properly adapted to the character of the minerals with which it was impregnated, there would probably have been some profit beyond the return of the capital invested.

It seems, from a comparison of the examples of the Exhibition, Budgee Budgee, and Eureka mines, that such reefs may be made remunerative when worked with appropriate appliances and with judgment and economy. The probability is that they could in many cases be made to pay if worked by small companies of a co-operative character, although perhaps incorporated for individual security. But the working expenses would require to be kept well in hand, the crushing plant to be effective, and at the same time adapted, for the highly mineralised stone of the contact reefs, and also so constructed as to admit of being readily transported elsewhere should the mine fail. The saving and treatment of the pyrites would require more attention than has hitherto been given to it, for in general nothing was done with the tailings except to facilitate their departure from the mill, and no care was taken to learn whether any gold was being carried away in them or not.

In some instances in past years I have obtained samples of pyrites from such mines in the district, which in all cases proved to be auriferous, up to over in one case 70 oz. to the ton of pyrites.

The want of success in the working of the contact reefs by incorporated companies in the past is brought well into view by comparison with the individual efforts of Mr. Peter Forsyth, an enterprising quartz miner, at Swift's Creek, who for some years past has perseveringly worked on his own account with satisfactory results on one or other of the contact reefs of that district. At the Budgee Budgee Reef the Messrs. Hardy and other miners are now working with prospects of ultimate success.

It seems probable to me that the auriferous contact reefs of Dargo, Swift's Creek, and Omeo will in the future be worked somewhat in the manner now indicated, and with remuneration to those engaged upon them. This would be a true revival of one branch of quartz-mining. It would not afford a field of operation for the promoter of companies, but it would give remunerative employment to men who wished to work on their own account, and who would be content with doing so in an unpretending manner, for moderate returns on the capital invested.

There is one question which I have not yet considered, namely, the probable origin of such reefs as those of Dargo.

Such quartz veins are found either in the intrusive plutonic rocks where laid bare by denudation, in the contact between them and Silurian sediments, or in the latter, where either metamorphosed into hornfels, or at a greater distance from the contact in a more normal condition. It is safe to assume that the quartz veins in the plutonic rocks once extended upwards into the sediments whose denudation has supplied the streams with the alluvial gold, and that those now found in the contact zone would, if traced to sufficient depths, pass into the intrusive rocks. Such veins fill fissures whose original width may have depended upon downthrow or upon a side shift which brought discordant parts of the walls together, and thus prevented the complete closing of the fissure. Narrow and regular veins, such as those at the Exhibition mine, indicate probably fissuring through homogeneous rocks, or without shifting of the sides of the fissure. As I have before said, the lodes which fill these fissures do not, as a rule, extend any distance down into the intrusive rock masses, but thin out, and are lost. The fissures were clearly formed at that time when the sedimentary crust was raised, and its strata opened and faulted during the time of the plutonic activity to which I have so frequently had occasion to refer in this series of papers. This took place probably at the close of the Silurian age; but it does not follow that these fissures were then filled with the quartz lodes and the minerals which we now find in them; nor can it be assumed that the fissures were opened once only; on the contrary, I think that, as to the veins at the Exhibition mine, they have been probably opened and widened by a second addition of quartz. I have observed places where the quartz was divided by seams carrying ores parallel to the walls of the lode, and a sample which I sliced and examined under the microscope confirmed this belief. I found the quartz to be crystallised, and that one growth of crystals started from the walls, being filled in by a confused mass of imperfect crystals in the centre. It must, however, be remembered in connection with this subject that fissuring of the rocks forming the contact zone would probably follow any of the great changes to which the plutonic masses, together with the adjoining sediments would be subjected, through cooling down of the former or general subsidence of the crust. The periods of time during which all the changes took place, from the invasion of the sediments until the cessation of plutonic activity in that area, were evidently geological periods, and not to be measured in years.

The fissures at the Exhibition mine are narrow, and the lodes do not include, as is the case elsewhere, fragments of the bounding rocks which have fallen in during the movements of the rocks, and thus become highly mineralised during the lode formation.

The gold in these contact lodes is almost invariably associated with large amounts of ores, such as arsenical and ordinary pyrites, copper pyrites, galena, and, more rarely, blende. Near the surface these ores become decomposed, and the honeycombed quartz which remains retains the gold, which was formerly included in the sulphides and arsenides in its cavities, or embedded in hydrated ores. The greater part of the ores and the gold are found within the walls of the lode, but it is very commonly the case that the rocks at each side are also not only much altered mineralogically, but also more or less impregnated with ores. The mineral alterations in the walls of the lode are more recognisable where the lode passes down into the plutonic rocks than where it is in contact schists. As an example of such alterations, I may quote the Eureka mine at Swift's Creek, where the reef passes through massive quartz mica diorites. I observed that the foot-wall of the lode was much lighter in colour than the hanging wall, as well as being impregnated with ordinary pyrites. A hand sample of the rock is crystalline-granular, and greenish yellow in tint. In a thin slice it can be seen that the felspars have been so much altered that no traces of any twinning remain, the crystals being either entirely kaolinised, or where less altered, having the appearance of one of the pinite minerals. Traces of the former presence of iron-magnesia mica remain as fibres of chlorite, and the quartz is of two kinds—namely, the crystalline grains of the original rock and a second generation of much smaller and very interlocking granules.

In some cases I have observed, in addition to such mineral alterations, that minerals in the walls of the lode have been structurally altered by crushing.

The extensive impregnation of this class of quartz lodes with various kinds of ores, the banded structure of some of the quartz veins, and the frequent restriction of the gold to some of the bands rather than to the others, the impregnation of the walls of the fissures with ores, and the extensive mineral alterations which have been made in the bounding rocks, all point, when taken together, to the formation of this class of contact veins by the action of aqueous solutions charged with mineral and metallic materials. It is probable that these solutions were heated, although not necessarily to any high temperature, for the observations made by Daubrée on the effects produced by the thermal waters at Plombières on the Roman masonry, and metallic objects therewith, show that a comparatively low temperature will suffice, even at the earth's surface, to bring about mineral alteration and the formation of ores.*

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* Memoire sur la relation des sources thermales de Plombières, &c. Annales des Mines, 1858, XIII., p. 227. Etudes et experiences synthétiques sur la Metamorphism, Mémoires présentés a l'Académie des Sciences, XVII., p. 98.

It may be well at this place to draw a distinction between the auriferous quartz veins and other veins of quartz which are found at or near the contacts, and which have, in three instances within my knowledge in Gippsland, been fruitlessly prospected for gold.

The class of quartz veins to which I now refer is not, so far as I have observed, auriferous, or even ore-bearing. At any rate, no gold has been found in them by any of the ordinary methods of examination.* They are either of quartz only or of quartz together with one or more characteristic minerals. In the neighbourhood of Dargo I have observed quartz veins of small size of this kind near or at the contacts composed of quartz with small schorl crystals. Far more clearly, however, is the distinction between the two classes of quartz veins to be seen near Omeo. The auriferous reefs which have been found and partly worked there are essentially of the character of those at Dargo, being veins of quartz mineralised by arsenical and ordinary pyrites and galena with gold, at the contact of quartz mica diorites with the regionally-metamorphosed schists. The features which I desire to bring out into view are there much more marked than at Dargo, and I therefore take my illustrations from them. Besides these auriferous quartz lodes, there are also throughout the neighbourhood of Omeo numerous veins, and even large masses of quartz, which fill fissures in or are interfoliated with the metamorphic schists, or traverse parts of the plutonic rocks. The quartz of these veins is in places milky in colour, and in others translucent and extremely crystalline. In addition to these veins of quartz only there are others of the same class which contain schorl or cleavable masses of felspar, or muscovite mica, or two or all of them together in varying proportions, so that veins may be extremely quartzose with but little proportion of minerals, or may be so charged with them as to become a variety of pegmatite.

A study of the veins composed of quartz alone, or of quartz with schorl, brings out certain features which are of moment in this consideration. The prismatic crystals of schorl are often penetrated by thin films of quartz, or have been broken across, the parts being removed from each other and separated by the silica. If such crystals are extracted, it is found that the quartz has perfectly moulded their most

* I now refer only to the Dargo and Omeo districts.

minute markings, and that, moreover, this moulding was completed after the crystals were formed. The fractures of the schorl crystals, the removal of the parts from each other, the penetration of films of quartz into small fissures in the crystals suggest that the silica, when this happened, was, as a whole, capable of some movement under a degree of pressure, and the moulding of the quartz to the schorl crystals shows that it was plastic. The supposition that the quartz may have been gradually deposited from solution round the crystals of schorl until the fissure was completely filled seems to be quite negatived by the observation that the schorl is not attached to the walls of the fissure, but "floats" free in the quartz. This requires, therefore, that the quartz should have been in such a state as would admit of movement, and yet in a condition far denser than that of an ordinary solution. These observations on the mode of occurrence of crystals of schorl in quartz veins are not new, but have been made and recorded long ago.* I now mention the particulars, as I have seen them at Omeo, as being necessary to the explanation which I desire to offer.

It seems to me that the above facts admit of only two alternative explanations. Either the quartz was in a molten condition when it filled the fissure, or it was in the condition of a solution in an extreme state of condensation. There is no evidence whatever in the adjoining rocks of any such elevation of temperature as would be necessary for the fusion of quartz, nor do I think that at the present day geologists would be inclined to admit an hypothesis based thereupon.† There remains, then, the second hypothesis, and this would be satisfied by the supposition that the quartz had been forced into the fissure in a colloidal condition, accompanied by such plutonic emanations as would suffice, together with small amounts of bases contained in the colloid silica to the formation of schorl.

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* For instance, see Bischoff, "Lehrbuch der Chemischen, und Physicalischen Geologie," Band II., 552.

† I observe some remarks by Professor Rosenbusch, which have a bearing upon this question. He says ("Microskopische Physiographie der Petrographisch wichtigen Mineralien"—2nd Edition, p. 344):—"Eine darstellung des quartzes aus schmelzflüssigen silikat-mutterlaugen ist bis darhin stets vergeblich versucht worden. Der Grund dürfte darin zusuchen sein, dass die künstlichen Silikat-schmelzen nicht wasserhaltig hergestellt werden können, wie es die natürlichen sind."

The occurrence of such quartz veins at the contacts and in the schists adjoining, as well as in the plutonic rocks, suggests the source of the silica.

It seems that in plutonic rocks, such as the quartz diorites of Dargo and Omeo, the most basic of the constituent minerals have been the first to crystallise out of the magma in definite forms, thus leaving it more silicious after each successive crystallisation. The gradually increasing acidity of such a magma may be inferred from the observations which I have recorded on the quartz diorites of Noyang,* where the successive intrusive rocks are increasingly silicious, and the latest of them are dykes composed of quartz and felspar only. The study of the Noyang rocks shows also that which has been abundantly proved elsewhere—namely, that the quartz consolidated from a plastic condition, which was almost certainly that of a colloid containing a certain but relatively small proportion of alkaline water, some of which can still be found in the minute fluid cavities, which in places fairly swarm in the now crystallised quartz. In these cases the silica was the last constituent to crystallise, and it moulded itself to the forms of the other minerals, and filled in their interspaces just as the quartz filled in the vein fissures, and moulded the schorl prisms in the case of the quartz veins in question.

It seems to me, therefore, more than probable that such quartz veins as these represent some of the residual silica of the plutonic magma, after the compound minerals had crystallised out, and that this residuum was squeezed out while in a colloid state into every adjoining fissure and plane of separation. No high temperature would, on this view, be necessary to produce these dyke-like quartz veins, for the exudation of the still colloidal silica was brought about by the reduction of temperature, which caused the plutonic magma to solidify.

On the strength of these grounds, I conclude that the quartz veins, which I desire to distinguish from those which are auriferous, solidified from the residual colloidal silica of the plutonic masses.

It may be said with great truth that these quartz veins are of plutonic origin, for they differ but little, except in

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* "The Rocks of Noyang." Transactions Royal Society of Victoria, Vol. XX., p. 18.

bulk or in the final conditions of their crystallisation, from the silica of the holocrystalline rocks.*

I may sum up my remarks by saying that these plutonic quartz veins were formed at the cessation of the invasion of the sediments by the great igneous masses, and when these latter were crystallising and the temperature had begun to lower. They have not produced mineral changes in the rocks containing them, nor are they ore-bearing.

The auriferous quartz veins of the kind found at Dargo were formed at a later time, when the temperature had fallen still more, and when the cooling solutions deposited their mineral or metallic burdens in the fissures they permeated, or were precipitated by other solutions percolating from the bounding rocks or from above. When these auriferous veins occur in the plutonic rocks, the "country" bounding the fissure is generally found to have been much altered, and to be also more or less charged with the same ores that enrich the lode. In these cases the fissuring and formation of the lode is clearly subsequent to the consolidation of the rocks.

Although the interval between these formative processes, that of the plutonic and auriferous quartz veins, was no doubt vast, for the cooling of the plutonic rocks and of the heated sediments must have extended over what we should call ages of time, yet both were parts of the same great sequence of events which commenced towards the close of the Silurian age, and extended far into the Devonian period before it terminated.

Conclusion.

I have found it always advantageous to summarise the conclusions to which the study of any subject has led. By so doing a clearer view of the field of inquiry is gained, the connection of the various observed facts becomes more apparent, relations show themselves which were not before seen, and it not infrequently happens that it is possible to frame a tentative hypothesis explaining the observed facts,

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* I have been gratified to find that these views, to which the study of metamorphism in the Gippsland Alps has led me, are substantially those which Professor Lehmann has recorded in his magnificent work on the origin of the crystalline schists. Among other passages which are worth the most serious consideration by geologists, I note his remarks on the subject of those quartz veins which I venture to term "plutonic." See p. 56—Die Entstehung der Altkrystallinische Schiefergesteine—Bonn—1884.

and serving as a test for the value of the work done. I propose, therefore, now to summarise the main results at which I consider myself to have arrived, and I shall also venture to suggest what seems to me, on broad lines, to be a possible explanation of the origin and formation of the auriferous quartz reefs of the district in question.

The quartz diorites of Dargo are evidently part of the masses of plutonic rocks which underlie all Gippsland, and which, by denudation, show at the surface in very many places, and at all elevations, from the sea-level up to the highest mountain tops. The Dargo area is one of a connected series which extend in the lower paleozoic formations for nearly fifty miles from the Tambo River, and then, if the same conditions continue, are covered from sight by the Upper Devonian rocks of the Avon River drainage area. The general direction of these intrusive areas is, as a whole, to the south-west, thus being approximately at right angles to the normal strike of the Silurian rocks of the district.

The immense forces connected with the intrusion of these rocks into the sediments may be inferred from the observation that in places these latter have been deflected from their normal strike, and lie alongside the intrusive rocks in a more or less east and west direction. This linear extension of areas of intrusive rocks across the direction of the prevalent strike I have also observed in places in the Omeo district, as, for instance, at Swift's Creek.

The prevalent strike of the Silurian strata in direction west of north indicates a direction of compression acting at right angles to it, and, I think, probably from the east. The east and west diversion of the strata in the neighbourhood of the intrusive area of Dargo is local, and may be due to pressure exerted by the molten magma when being thrust into the opening sediments. There was, I think, an elevation of the crust, accompanied by an upward movement of great force by the plutonic magma, which filled in and probably thrust back the opening strata. The best explanation of the phenomena which have imprinted themselves upon the rocks is one in this case which points to subsidence in an adjoining area to the eastward, probably beyond the present bounds of the continent, acting against a rigid part of the crust of the earth. By this the strata were forced to give way, and their movement was assisted by the upward thrust of the imprisoned magmas, acting under the weight of the subsiding area, as fluids under hydrostatic pressure. The weakest portion of the crust gave way, and elevation was the result. The accumulation of the immense thicknesses of the Silurian formations, estimated by Dr. Selwyn as being at least 35,000 feet,* implies a long-continued period of depression.

My own observations in Gippsland have shown me reason to believe that the south-eastern part of Australia, as evidenced in the Australian Alps, was subject to extensive elevation at the close of the Silurian age, which culminated in a volcanic period, evidenced by the Snowy River porphyries, which are stratigraphically between the Upper Silurian strata and the Middle Devonian beds of Buchan.

The compression of the Silurian formations into acute folds, together with elevation of the crust, would tend to give room to the imprisoned plutonic magmas when forced into the rising crust of the earth. Such movements as these must have been necessary to produce the results which denudation has laid bare at Dargo and the adjoining areas.

The contact rocks produced by the action of the plutonic masses upon the adjacent sediments are mainly varieties of schistose and crystalline hornfels, normal in their character, and not differing materially from similar rocks which have been observed and described in other parts of the world.

One of the most interesting features in connection with the Dargo and neighbouring areas are the auriferous quartz lodes at the contacts. Their interest and importance do not arise out of their economic value, which is small, but from the light which their study is calculated to throw in the future, not only upon their own origin and formation, but also on that of auriferous quartz reefs generally.

In these notes I have described the relations of the contact quartz lodes and veins to the adjoining formations, and I shall now speak of the quartz reefs in the Silurian tracts at a distance from the intrusive areas.

The quartz reefs and smaller veins in the Silurian formations of North Gippsland were formed after the sediments were invaded by the plutonic rocks, and before there had been complete subsequent cooling and consolidation. The limits of this space of time are fixed by the folding together of the Silurian strata† and the complete stratigraphical

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* Intercolonial Exhibition Essays, 1886. Notes on the Physical Geography and Geology of Victoria, p. 11.

† In parts of North Gippsland the Upper Silurian beds have been folded in this manner, as well as the Lower Silurian.

break below the Upper Devonian formations. The quartz veins cross, or are contained in the former, but do not, wherever the contact of the two formations can be observed, pass up into the latter; indeed, the lowest beds of the Upper Devonian series are made up largely in places of quartz pebbles derived from the denuded Silurian rocks.*

As an illustration of the Silurian tracts in which auriferous quartz reefs are found, I take the district north of Dargo for brief reference. A mental picture of it will be of a great tract of highly-inclined, alternating quartzose and argillaceous beds, rising to over three thousand feet above its lowest valleys.

The total thickness of these Silurian rocks is much greater than the depth from the highest mountain summit to the deepest valley, for within them there are no traces of the nearness underfoot of the plutonic rocks.

This great mass of sediments, which covers more than two hundred square miles between the Dargo and Wonnangatta rivers is traversed, as may be seen in the workings of mines, as well as in natural and artificial rock sections, by joints and fissures, the results of innumerable compressions, dislocations, elevations, and depressions by which the strata have been affected. Very many of these lie in the direction of the strike, but others cross it, as well as the dip or the cleavage, at various angles. They all form, when taken in the aggregate, as compared with the great mass of mountains, a more or less connected network of separations in the rocks. Many of them are only planes of discontinuity, but others have been filled by vein quartz from several feet in thickness down to the width of scarce more than a sheet of paper. The fissures thus filled by "reefs" of quartz have in their turn been faulted, so that in many places the following of them in mining is a matter of great difficulty.

In certain localities the quartz is more mineralised than in others, and here it is more usual to find the reefs payably auriferous. It may prove that in the area referred to, as in others, where it has been shown to be the case by the valuable researches of Mr. R. A. F. Murray, the auriferous quartz reefs lie within a certain band, according with the strike of the sedimentary rocks. In the district of which I am now speaking, and of which Grant may be taken as the centre,

* The occurrence of such conglomerates suggests that the lowest beds of the Upper Devonian series may in places be auriferous.

veins of quartz occur throughout the mass of the Silurian formations from the summits of the mountains down to the bottoms of the deepest valleys. The great thickness of these rocks, which has been denuded during the long continuance of terrestrial conditions in the Australian Alps, was also similarly traversed by quartz veins, as is proved by the quartz gravels of the old rivers of Middle Miocene age which are now situated almost on the summits of the mountains, more or less covered up by flows of basaltic lava.*

To complete the mental picture, one must also conceive the Silurian strata with their quartz veins, extending downwards to the plutonic rock masses—at whatever depth below the present surface these may be situated. This inference is fully justified by that which one can observe at places where, as at Dargo, denudation has laid bare the contact of the two formations.

In endeavouring to explain the formation of the quartz reefs in this vast mass of Silurian sediments, which is only the remains of a once much larger mass, it seems to me that one is forced to assign as a cause the action of solutions which have derived their silica and their gold also from the strata through which they have percolated. Herein they are distinguished from these quartz veins to which I have before referred, which are found in the plutonic rocks, or in the schists immediately adjoining them.

If I am correct in saying that they were formed during the interval of time from the close of the Upper Silurian period to the close of the Middle Devonian period, then it is probable that their formation was due to causes which lay between two extremes. That is to say, to solutions intermediate in character between those which existed at the time of the invasion of the sediments by the plutonic rocks, or to those which existed at the time when the plutonic action had abated or had almost died out. The former would be mineralised solutions acting under a high temperature and great pressure; the latter would be solutions remaining after a long course of mineral regeneration, and under conditions of much lowered temperature and pressure. The action of solutions of the former kind seems to have been towards the regeneration of the sediments as metamorphic schists. As to the latter, we may suspect that they were most likely

* The plant beds contain, among others, Cinnamomum polymorphoides (M'Coy).

to deposit those combinations which had remained in solution the longest, or which had been taken up from the rock masses through which they circulated. I think reasons can be shown for believing that silica would be amongst those substances, and also gold.

If the quartz reefs were formed, as I believe, towards the close of the period of plutonic and volcanic activity, it may not be necessary to assume any great elevation of temperature or of pressure to account for their formation. Indeed, as I have before said, the deposition of the quartz from solutions, and the production of the ores found in the contact lodes, would be most likely to take place at a falling temperature, when the solutions were no longer so well able to carry their mineral burdens.

But there is another view which must be considered when looking round for the probable source of the silica which we now see as the quartz of the reefs.

We learn from the investigations of Mr. J. Cosmo Newbery, C.M.G., that the waters percolating from the surface downwards are charged with ammoniacal compounds of which the acid carbonate is the most energetic in its action on the silicate rocks. He has shown that ammonia can be obtained from almost any, if not all, of our springs and subterranean waters, and that "such ammoniacal solutions, especially that of the acid carbonate, can carry away silica in solution, and penetrating to great depths become no doubt one of the active agents in metamorphism." *

It is probable that such agencies which are now active may have been just as powerful in the time when these quartz reefs in question were formed. That time was one of volcanic activity, and probably of a land surface, and if such were the case the waters percolating down into the earth would be ammoniacal, and at times strongly so.

It is, however, not probable that one set of reactions only was concerned in the formation of the quartz reefs. The silica may have been present, not only in solutions in the manner suggested by Mr. Newbery's experiments and researches, but also as a residuum in much older solutions which had taken part in metamorphic processes.

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* Reports of Progress Geological Survey of Victoria, Part IV. and Part V. Laboratory Report, page 166, *et infra.* "Formation of Hyalite by the Action of Ammonia"—Transactions of the Royal Society of Victoria, Vol. XV., page 49.

It remains now for me to point out a possible source of the gold contained in the reefs. It might be considered that the gold and silver found in the contact reefs had an origin connected with the plutonic masses, but this explanation would not apply to those reefs and veins which are to be found in the Silurian rocks spoken of by me previously.

Sonstadt* has proved the existence of gold in sea water, and, according to Wurtz,† it is therein at the rate of one dollar in value to every twenty-five tons of water. Such being the case, it seems probable that the waters of the Paleozoic oceans did not contain less gold in solution than those of the present time. The deposition of the enormous thickness of Silurian sediments,‡ much of which consisted of fine silt and mud containing organic substances, must have necessarily included a certain amount of sea water. This, although as to some of the elements and combinations —as, for instance, gold—a solution of extreme dilution, yet would, in the aggregate, contain an enormous amount even of the rarer elements. Hence these sediments must, on this view, have included a large amount of gold diffused through them in solution, possibly, as at the present time, in combination with iodine.

The observations and experiments of Daintree, as confirmed by Wilkinson,§ show that the solution of gold chloride is precipitated in the presence of organic substances. The occurrence of auriferous pyrites deposited upon a piece of wood taken from the drift immediately below the basalt at Ballarat|| and of gold deposited upon coal at Vöröspatak¶ still further illustrates this reaction, and, as relates to the former instance, it shows that even in recent times subterranean waters conveyed gold in solution. That they

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* Roth—*Chemische Geologie*, Vol. I., p. 492.

† Hunt—*Chemical and Geological Essays*, p. 237.

‡ "Making due allowance for this repetition of the same beds at the surface, the total vertical thickness of the series can scarcely be estimated at less than 35,000 feet." Intercolonial Exhibition Essays, 1866. "Notes on the Physical Geography, Geology, and Mineralogy of Victoria," by Alfred R. C. Selwyn and George H. F. Ulrich, p. 11.

§ Mr. Daintree's discovery consisted in the fact that a speck of gold lying in a solution of chloride of gold increased to several times its original size after a small piece of cork had, by accident, fallen into the solution. This was confirmed by further experiment by Mr. Chas. Wilkinson. Ibid, p. 24.

|| Ibid, p. 56. The pyrites gave a yield, on assay, at the rate of 40 ozs. of gold per ton.

¶ Recorded by K. V. Fritch. Roth—Chemische Geologic, Vol. I., p. 602.

do so now is shown by the observation made by Mr. H. Y. L. Brown in the Alison mine at Costerfield, where a mammillary, or stalactitical crust, had been deposited on the roof of one of the drives, which contained gold, together with ores of iron and antimony.*

Such sediments as those of Silurian times could not lose their saline waters until they became elevated above the sea level as dry land, and this seems only to have been the case with them during the earlier part of the Devonian age, as a consequence of the great terrestrial movements to which I have before referred. So long as the saline waters remained within the sediments they would afford materials for mineral regeneration. The gold in solution, or possibly also diffused in a metallic, finely-divided state within certain beds, if precipitated by organic substances, would be a source of supply under a series of reactions which are conceivable, as also the final deposition of the gold, together with silica, in the fissures which gave passage to the solutions.

It would be idle to attempt to sketch out the course of such reactions in the absence of knowledge as to the effect of the very different conditions of temperature and pressure at great depths within the earth. It suffices for my purpose if I have been able to indicate the possible source of the gold and the mode of its final resting-place in the quartz reefs. The experiments of Daintree and Wilkinson suggest the precipitation of the gold in solution by organic materials in the sediments; and as to the formation of the quartz reefs, together with the gold, the experiments made by Bischoff† show that the mutual reaction of solutions of gold chloride and alkaline silicates may have played a part.

The following are the conclusions to which I have arrived on the foregoing subjects :—

(1.) The Silurian sediments included a certain amount of the waters of the seas in which they were laid down, and thus contained some of the materials for their mineral regeneration and the formation of metalliferous lodes.

(2.) The folding, compression, metamorphism, and invasion by plutonic rocks of these sediments occurred at the close of the Silurian age, followed by—

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* J. Cosmo Newbery, B.Sc., Laboratory (page 175)—Reports of Progress, Part IV., Geological Survey of Victoria.

† *Lehrbuch der Chemischen und Physicalischen Geologie* (Part III., page 843).

(3.) The elevation of the crust of the earth to a land surface during the early part of the Devonian age, and the manifestation of plutonic action in volcanoes (Snowy River district).

(4.) The cessation of the plutonic and volcanic action and the subsidence of the land in the Middle Devonian period.

(5.) The intrusion of the quartz diorites of Dargo was probably during the latter part of the time mentioned in (2).

(6.) The formation of the auriferous contact and other quartz reefs of the district referred to in these notes was probably in some part of the time mentioned in (3), if not in the earlier part of (4).

These, then, are the general conclusions which I have reached as to the origin and formation of the auriferous reefs of North Gippsland, whether at the contacts or in the Silurian formations. The tentative hypothesis which I have briefly sketched pretends to no more than an attempt to throw some light into the dark places of a most difficult subject. Whether I have in any measure approached a solution of the question I must leave to competent authorities to decide, merely adding that, from my point of view, the hypothesis seems to harmonise with observed facts, and not to run counter to the requirements of geological chemistry.

My views, if resting on a foundation of truth, would have an important bearing upon the question of the future continuance of our quartz reefs in depth. It would follow as a corollary to them that the quartz reefs in any part of Victoria might be expected to descend in a more or less connected manner through the whole thickness of the Silurian formations, and to end only as contact lodes at the subterranean plutonic rocks.

EXPLANATION OF THE PLATES.

Plate I.

Horizontal plan of middle adit at the Exhibition mine, Orr's Creek, Dargo, looking west. The numbers 1, 2, 3, 4, refer to the sections given in the plate across the adit.

Fig. 1. (*a*) Quartz vein six to nine inches wide, with gold, accompanied by galena and ordinary iron pyrites. (*b* and *b′*) Narrow quartz veins carrying gold, very finely divided, and being in places merely thin partings. (*c*) Hornfels rock.

Fig. 2. (*a*) Dyke of much decomposed igneous rock. (*b* and *b'*) Quartz veins with gold, arsenical and iron pyrites. (*c*) Hornfels.

Fig. 3. (*a*) Quartz vein, with gold and pyrites. (*b*) A narrow clay seam. (*c*) Hornfels. The portion of country included between *a* and *b* is much mineralised.

Fig. 4. (*a*) Quartz vein, with gold and iron pyrites. (*b*) Decomposed dyke of quartz porphyr. (*c*) Hornfels.

Plate II.

Fig. 1. Section of reef at the Eureka mine, Tucker Creek. (*a*) Quartz-mica diorite. (*b*) Quartz vein about 18 inches in width, with pyrites and a little gold. (*c*) Porphyrite dyke. Dip to the east.

Fig. 2. Section of lode at Budgee Budgee mine, Granite Creek. (*a*) Quartz-mica diorite. (*b*) Mineralised band of diorite, carrying copper pyrites. (*c*) Clay seam. (*d*) Quartz vein, with gold and pyrites. (*e*) Quartz-mica diorite. The lode dips north.

Fig. 3. Ground plan of the reef in the Exhibition mine, showing the manner in which "splices" take place between the main vein and smaller veins of quartz from the northern side. (*a*, *a'*, *a''*) Quartz veins, with gold, galena, and iron pyrites. (*b*) Hornfels. (*c c'*) Walls of the lode country.

Fig. 4. Section of the strata at Stringer's Creek. (*a* and *c*) Fine-grained sandstone. (*b*, *d* and *f*) Fine-grained slaty rock. (*e*) Sandstone, coarser grained than *a* and *b* and having much argillaceous material, together with grains of quartz. In this rock are numerous narrow veins of crystallised quartz (*g*) which do not pass into the beds on either side. In places these veins can be seen to have been filled by quartz crystallisations, commencing at each side and meeting in the middle. Under the microscope a thin slice of this bed shows that a considerable silicification has taken place throughout the rock, and that the filling of the transverse veins has in all probability been connected therewith, leaving the slaty beds adjoining but little affected. The slaty cleavage, which has affected the beds *b*, *d*, *f*, has not acted upon *e*.